Recommendations to improve coordinated nontidal monitoring, assessment, and communication activities in support of Chesapeake Bay restoration: A report addressing STAC recommendation for monitoring reallocation, 2009

A Report to the Monitoring Realignment Action Team

Effectiveness and Optimization Issue Team

August 2009

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Executive Summary

The Chesapeake Bay Program's nontidal workgroup and MRAT optimization and effectiveness issue team, consisting of federal, state, river-basin commissions, and academic partners, have identified items needed to address the information needs to "assess the effectiveness of management actions" that were in the Chesapeake Bay's Scientific and Technical Advisory Committee (STAC) review of the Chesapeake Bay monitoring program (STAC 2009a). The workgroup reviewed current programs and activities to identify opportunities to address the information needs and determined where funding is required to support additional activities. Four primary topics have been identified where increased funding or partner efforts are needed 1) improve the Nontidal Water-Quality Monitoring Network, 2) enhance assessment of existing information, 3) utilize small watershed studies to assess effects of management actions, and 4) develop additional communication products.

Recommended activities were developed for each topic to improve the watershed monitoring, assessment, and communication. A summary of these recommendations for enhanced effort and funding include:

1. Maintain the continuity and increase stewardship of the current CB nontidal water-quality network (NTN) and its data -- *the historical investment is substantial and is crucial to maintain. We must improve management of the data and make it more accessible to the science and management communities.*

2. Enhance data analysis of the NTN data and selected supplemental networks to document and communicate the status of trends in water quality and explain changes in water-quality condition—*1) Utilize long-term data sets to communicate patterns of change over time and explain effects of changes in the watershed. 2) Utilize sites with the shorter period of record to describe the status of concentrations and loads across the watershed to support targeting of restoration efforts. 3) Refine methods to use additional partner monitoring to improve spatial resolution of current assessments. 4) Use available data to evaluate and improve watershed models.*

3. Increase stewardship and improve the information of important watershed activities including tracking management actions.—*The MRAT team has concluded that the implementation data available at this time is insufficient for the evaluation of the effects of management actions. Data-management efforts may be focused on those watersheds with active monitoring programs to support evaluation of management actions. An effort is needed to: 1) assemble and document historical information on land use, point sources, population, and agricultural activity, 2) create a sustainable process for tracking watershed information in the future, and 3) make this information available to support assessment, research, and modeling efforts.*

4. Make strategic improvements to the NTN to support assessment the effects of management actions in a more quantitative fashion in the future — *additional sites in:*
   a. watersheds with predominantly urban land use,

b. watersheds with predominantly agricultural land use,

c. Coastal Plain watersheds, and

d. basins where substantial BMP investments are planned, and other watersheds that can be used for baseline conditions.

5. Utilize information from small watershed studies to better assess the effectiveness of management actions.—*Synthesize lessons learned in past and on-going small watershed studies and ground-water quality studies and integrate these results into communication products to support watershed assessments and management decisions.*

6. Improve communication products to help managers better prioritize and evaluate management actions. — *Incorporate status and trends indicators in the CBP "Bay Barometer" to support management and public awareness on watershed conditions. Summarize results from enhanced data analysis to communicate understanding of factors affecting change in water quality to a broad audience.*

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Introduction

During 2008 the Chesapeake Bay's Scientific and Technical Advisory Committee (STAC) conducted a survey of senior managers in the Chesapeake Region to assess their information needs based on products from the Chesapeake Bay Program's monitoring program. In 2009, STAC issued a draft report "Development and

Implementation of a Process for Establishing Chesapeake Bay Program's Monitoring Program Priorities and Objectives". The following information needs were identified for the watershed monitoring and assessment program. The needs include the following:

- Determining the effectiveness of management actions in the Chesapeake Bay Watershed.
- Help guide decisions to prioritize watersheds and pollutant sources for management actions.
- Estimate changes in nutrient and sediment concentrations over time.
- Estimate nutrient and sediment load changes over time and relate to jurisdictional and intra-jurisdictional loading reduction goals (tributary strategies).
- Better understand the condition and trends of water quality at different spatial scales and in different land uses (e.g. agricultural and urban areas) to help prioritize the most significant problem areas.
- Provide a sound foundation to communicate information about water quality in the Bay watershed that is relevant to the public and decision-makers.

Scope of report

This report is intended to provide recommendations for adjustments to the Chesapeake Bay nontidal monitoring program and the technical basis for those recommendations. These recommendations are intended to serve the needs of the monitoring realignment action team as it responds to the Chesapeake Bay Management Board. This report also provides additional complementary information in support of Presidential Executive Order (E.O.) # 13508 (Chesapeake Bay Protection and Restoration), May 12, 2009. The recommended activities will enhance the coordinated watershed monitoring and assessment throughout the Chesapeake Bay Watershed and address the gaps in the watershed monitoring program identified during the STAC review (listed above) of the monitoring program.

Potential Activities for Improved Monitoring and Assessment

Nontidal monitoring, analysis and reporting for the Chesapeake Bay Partnership have historically been coordinated through the Chesapeake Bay Program's Monitoring and Analysis Subcommittee (MASC) and its nontidal workgroup. Each state and key federal partners and river basin commissions, including EPA, USGS, ICPRB, and SRBC, provide an active contribution to nontidal monitoring and analysis.

The Chesapeake Bay nontidal network (NTN) is a network of 85 streamflow gages and water-quality sampling sites operated across the watershed. This network provides the principal data for reporting of water-quality conditions in the watershed including nutrient and sediment loads and trends in loads and concentration. Additional monitoring data, such as those used for the recently developed stream-health indicator, have been brought in to enhance the assessment of the watershed.

The recommendations and supporting analysis presented in this report focus on the following four areas:1) improving the Nontidal Water-Quality Monitoring Network, 2) enhancing assessments of existing information, 3) utilizing small watershed studies to assess effects of management actions, and 4) developing additional communication products. These recommendations are a compilation of comments and insights from the MRAT optimization and effectiveness workgroup which includes members of the nontidal workgroup and is intended to guide future activities in a way that more fully meets the needs of the Chesapeake Bay management and restoration effort.

Improve the Nontidal Water-Quality Monitoring Network

The current Chesapeake Bay NTN provides the foundational data for all analysis and communication of the status and changes in water quality conditions within the Chesapeake Bay Watershed. This network has evolved significantly since coordinated sampling began in the 1970's. The following discussion outlines an analysis of the current network and describes potential improvements to meet changing management information needs.

The current network was established in response to the landmark document *Chesapeake 2000*, where the Chesapeake Bay Program (CBP) and its partner State and Federal agencies agreed to improve water-quality in the Bay by meeting water-quality criteria for dissolved oxygen, water clarity and chlorophyll *a* by 2010 (CBPO, 1999). Excess nutrient and sediment inputs from rivers draining to the estuary are commonly responsible for the failure of some Bay segments to meet these criteria. Therefore, nutrient and sediment loadings must be reduced in the nontidal waters of the Chesapeake Bay Watershed to achieve these goals. To this end, the CBP's partners are implementing management actions through the tributary strategy process to expedite nutrient and sediment pollutant reduction. The CBP developed a nontidal watershed water-quality network in 2004 to monitor and assess the water-quality in the Chesapeake Bay Watershed. The original objectives of the nontidal network were:

(1) measure and assess the status and trends of nutrient and sediment concentrations and loads in the tributary strategy basins across the watershed

(2) help assess the factors affecting nutrient and sediment status and trends

(3) improve calibration and verification of partners' watershed models (CBPO 2004)

Originally over 200 candidate sites were recommended to address these objectives. The current network has 85 sites consisting of 67 sites fully implemented ("primary" sites) with another 18 sites partially implemented ("secondary" sites) (Figure 1).

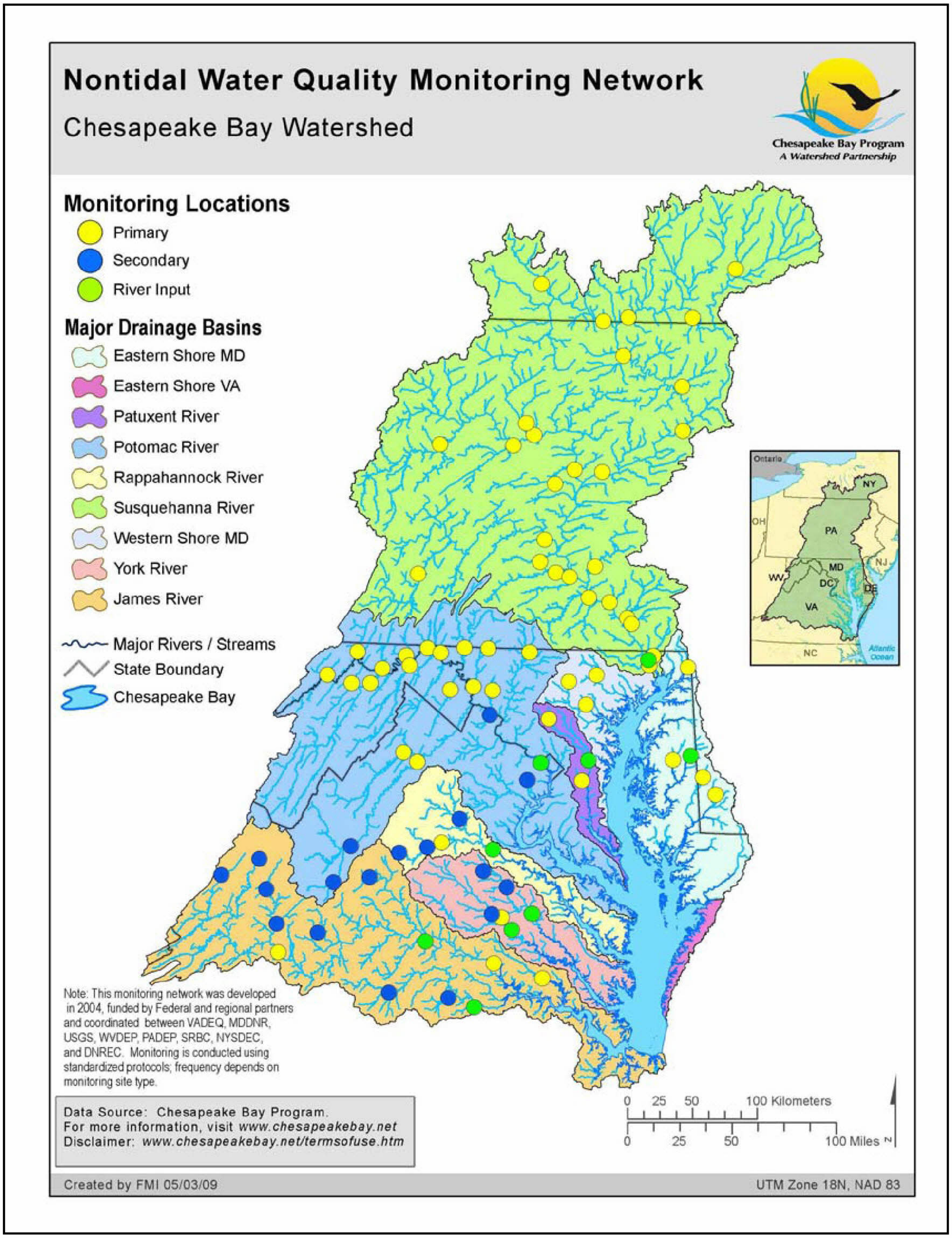

Figure 1: Current Chesapeake Bay Program's nontidal water quality monitoring network

Revised Monitoring Objectives

The objectives of the NTN must be significantly revised in order to accommodate priorities of partner organizations as identified in the 2009 STAC report. The following revised objectives reflect a balance between the long-term monitoring goals of CBP partners and the increased need for tracking of changes that may result from management actions (restoration) and other changes occurring within the watershed.

- Measure and assess the status and trends of nutrient and sediment concentrations and loads in:
    - Major tributaries and sub watersheds
    - Selected tributary strategy basins;
- Provide data suitable for the assessment of factors affecting nutrient and sediment status and trends from major pollutant source sectors;
- Measure and assess the effects of targeted management and land-use change;
- Improve calibration and verification of partners' watershed models;
- Support spatial and topical prioritization of restoration and preservation;

Analysis of the Network to Address Revised Objectives

A detailed analysis of the current NT network has been conducted in reference to both historical and revised objectives. This analysis revealed both strengths and weaknesses in the network. One of the original drivers for the design of the NTN was to capture monitoring sites within tributary strategy basins across the watershed. The Chesapeake Bay Watershed tributary strategy basins are composed of nine major tributary basins that are further divided into thirty-six smaller basins based on political jurisdictions (Figure 2). A nutrient and sediment cap allocation is designated for each basin based on the CBP watershed model. These allocations are the basis for nutrient and sediment load reduction implementation plans for jurisdictions. Designing a monitoring plan around these regulatory-determined basins has proven impractical, as determining the loads from each of these 36 basins requires more resources than available because many tributary strategy basins cannot be monitored effectively at a single monitoring location. It is also the case that the narrow scope of trying to design a network around political boundaries leaves many gaps in targeted source sectors and smaller watersheds.

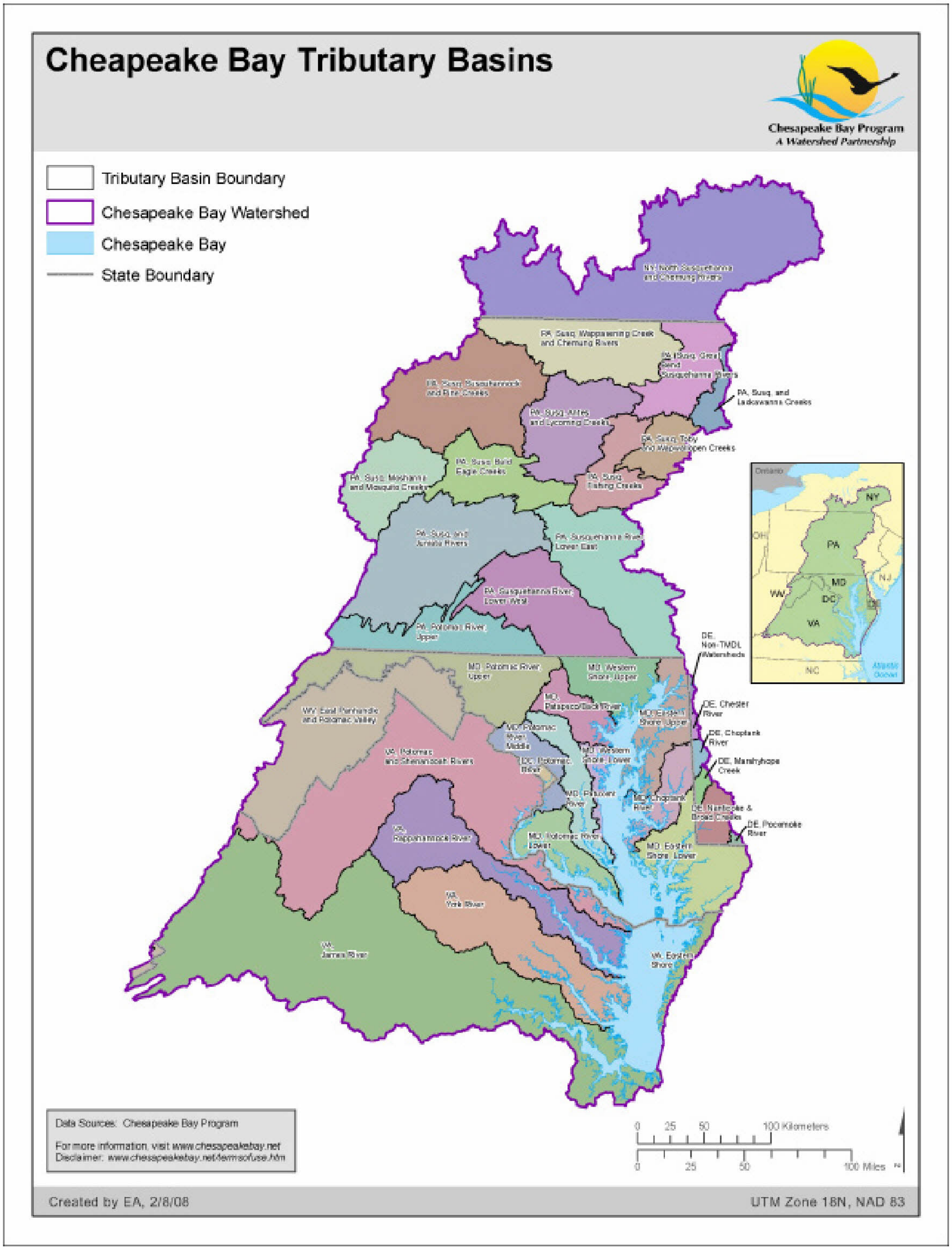

Figure 2: Chesapeake Bay Tributary Strategy Basins

An analysis of land cover characteristics within the watersheds of monitoring sites was used as a simplified surrogate of nonpoint source pollution sectors measured by the NTN. A graphical summary of generalized land cover characteristics in watersheds throughout the region is shown in figure 3 and is compared to the characteristics as represented in the 92 NTN sites. These diagrams show land cover in the watershed as a graphical combination of agriculture, urban, and forest lands in percent. For this analysis, a watershed was determined for each stream reach that drains an area greater than 10 square kilometers. Thus, each reach is considered an independent member of the target population of steams of interest.

The figure demonstrates key characteristics of the monitoring network as compared to the watershed population. 1) The NTN is mostly comprised of larger streams (greater than 1000 square kilometers) with primarily forest land cover. 2) Watersheds with greater proportions of agriculture, up to about 60 percent, are represented in the NTN; however many watersheds with greater proportions of agriculture exist and are not monitored. 3) Only two sites encompass more than 50 percent urban lands; while many small watersheds have greater proportions of urban lands.

A general consensus of scientists (STAC, in preparation) suggests that inferring cause-effect relations in stream quality is most successful in watersheds with relatively homogeneous land cover and land management practices. Such watersheds exist within the Chesapeake Bay basin yet most commonly are the smaller sub-basins.

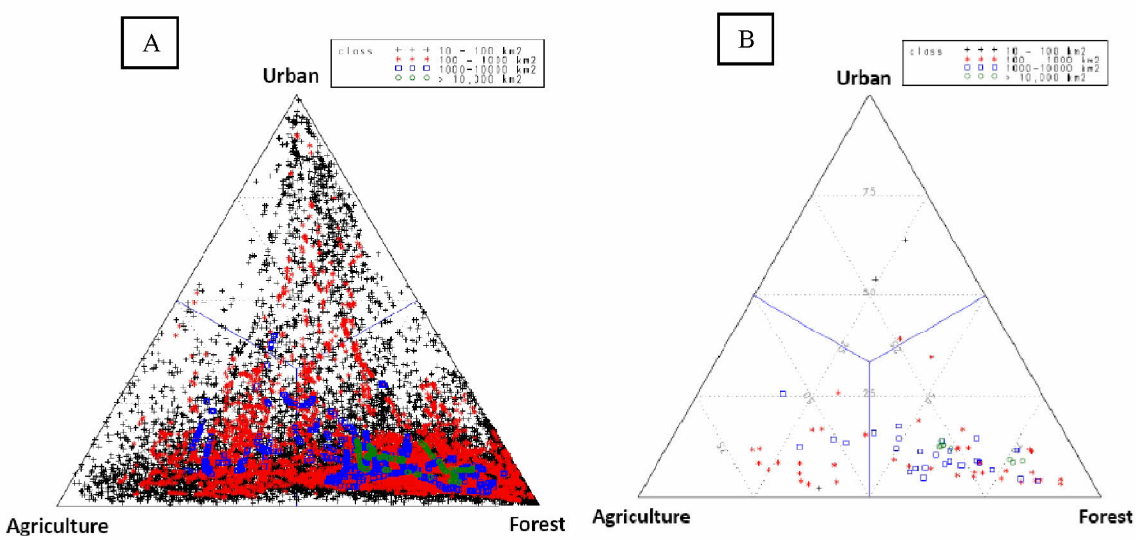

Figure 3. Generalized watershed land cover characterization for A) all reaches in the Chesapeake Bay Watershed greater than 10 square kilometers and B) the Chesapeake Bay Enhanced nontidal network.

Further review of the monitoring network and long-term monitoring data were conducted to determine strengths and weakness to use as a guide for optimization of future monitoring. These include:

Strengths:

- Implementation has led to a strong network of consistent sample collection that provides an annual analysis of status trends and long-term trends basinwide.
- Loads and long-term trends are well tracked at the River-Input monitoring locations and many subwatersheds in the watershed.
- Several tributary strategy basins have monitoring underway that will assist in tracking progress in restoration.
- Many important subwatersheds were added with the enhanced nontidal network (2004-2006) that, over time, will increase spatial resolution of current information.

Weakness:

- Many (or most) tributary strategy watersheds are not monitored at locations that will facilitate assessments of progress towards meeting water quality targets.
- Many important regions and source sectors have few monitoring locations or are assessed only by sites with large watersheds. Some of these areas include:
  - Eastern Shore tributaries
  - Small agricultural watersheds (various agriculture practice types)
  - Urban streams (small and large)
  - Small watersheds (all land cover)
  - Regions undergoing change and development.

Network Design considerations

The following outline the desired characteristics of an improved nontidal monitoring network and is intended as a guide to target enhancements to the current network to address evolving goals. The primary network should consist of stream-quality monitoring stations located at gaging stations, collecting fixed-frequency samples and supplemental storm-flow samples, and using comparable collection techniques as described in previous implementation documents. The purpose for these criteria is to facilitate frequent compilation and analysis of network data using consistent analysis techniques on a frequent and recurring basis. These criteria for network sites, however, do not preclude the use of data from State and other monitoring data for supplemental and complimentary analyses and reporting. The use of supplemental data is considered essential and encouraged to accomplish many of the objectives of Chesapeake Watershed restoration and management.

The extensive scope of the revised objectives for the nontidal network implies that stream monitoring locations must represent a wide range of sizes and physical settings. The following list and discussion presents some of the most important features that should be represented. It is appropriate that a gradient of conditions is represented and particularly important that watersheds with characteristics among the most extreme are included.

- Size range:
  - Tributaries and large subwatersheds
  - Tributary strategy basins and smaller subwatersheds;
  - Key pollutant source sectors (small watersheds)
- Spatial distribution:
  - Ensure appropriate density across the watershed
  - Monitor smaller streams that drain directly to the tidal system rather than draining to the RIM sites.
- Hydrologic setting;
  - Representation of principal physiographic settings
- Source Sectors
  - Point-sources
  - Urban and suburban land
  - Forest
  - Agriculture (including row crops, pasture, and animal feeding operations)
- Managed and changing watersheds
  - Targeted agricultural practice implementation
  - Targeted urban restoration areas
  - Areas undergoing significant urban and suburban development

Potential changes to network

Given current budgets, it is unrealistic to expect full implementation of the NT network so we propose the following options to enhance the network: In all of these categories, strong preference should go towards sites that have some historical data record of the important variables. It is also crucial to maintain the continuity and increase stewardship of the current CB nontidal water-quality network and its data as the historical investment is substantial and is crucial to maintain. We must improve management of the data and make it more accessible to the science and management communities. Being able to compare newly collected data to data from a decade or more ago can be highly useful in understanding long-term changes in the watershed. Recommended changes to the NT network are as follows:

- Add more monitoring sites to address selected under-represented source sectors: urban and suburban
    - more analysis of other under-represented land uses and source sectors may be needed (long-term need)
- Add more monitoring sites to address small watersheds
    - add these sites based on existing or proposed intensive small watershed investigations, or if possible, based on focused BMPs or point source controls. Possible intensive small watershed investigations to partner with include the studies in watersheds identified by STAC that will have increased implementation funded through the Farm Bill (STAC 2009b).
    - consider different sampling frequency and load estimation techniques for smaller watershed sizes. Use of real-time water-quality surrogates is likely to be very useful here. Link directly with water pollution abatement actions.
- Add more monitoring sites to coastal plain physiographic region to improve load estimates and integrate with tidal monitoring.
    - consider designing systems of ground-water observations in the coastal plain that can be used to provide quantitative estimates of nitrate fluxes into segments of the tidal system.

All of these options would improve watershed model calibration in spatial areas including urban/suburban, small basins, coastal plain and other spatial gaps.

Enhance assessment of existing information

Based on a review of the monitoring priorities identified in the STAC report (STAC 2009a), it is clear that a more strategic approach to analysis and reporting of results from the nontidal network and selected supplemental networks is required. An annual report of conditions including trends in concentrations and constituent loads has been prepared based on the 32 long-term sites since 1998. However, some of this information has not been included in more widely distributed products such as the Chesapeake Bay Program's annual communication product "Bay Barometer" and may not have reached intended audiences. In addition, more analysis and reporting are required for additional sites in the enhanced NTN (now 85 sites).

The following sections describe proposed approaches to more fully utilize the nontidal network and supplemental data to achieve the following goals:

- Describe the status of water-quality conditions to better focus management actions,
- Document water-quality change, and
- Explain water-quality change.

Document Status of Water-Quality Conditions

STAC identified the need for information to help guide the prioritization of watersheds for management actions (STAC 2009a). Quality information on the status of water quality conditions in the watershed will aid in spatially targeting restoration and preservation activities. Detailed and descriptive information on current water quality conditions is needed to identify which areas of the watershed to focus reduction efforts in nutrients and sediment pollution and which areas to protect where there is suitable water quality. Developing these more detailed descriptions requires an investment in analysis activities and communication-product development based on the nontidal network and supplemental data. Potential activities to increase the documentation of the status of water-quality conditions include:

- Analyze and report on data from the newer sites in the NT network, which includes sites that will soon have 5 years of monitoring data (approximately 40 more sites), to provide improved information on the spatial distribution of loads and concentrations of nutrients and sediment in the watershed. These data will be used to describe the role of ground-water inputs, point sources, and surface runoff sources in water quality conditions. These data can also be used to evaluate and improve watershed models.
- Improve approaches to analysis and reporting of the results from long-term monitoring (sites with more than 20 years of water quality data), to help better understand variations driven by year-to-year changes in hydrologic conditions and those that are driven by changes in land-use practices and point source controls. This includes refining approaches to communicating these results to decision makers and the public.
- Present current conditions assessment in a long-term context to improve the understanding of the role of natural variability and time lags on water quality in the Bay watershed.
- Continue to use the CBP modeling tools (USGS SPARROW models, CBP Watershed Model, and landuse models) to help identify locations expected to have high nutrient and sediment loads to the Bay. Identify and report on discrepancies between monitoring information and model predictions to better identify areas where improved understanding of hydrologic processes is needed. Monitoring data are needed to improve model simulations of different source areas (forests, urban, and agricultural areas).
- Use the new stream health indicator as a tool to identify locations where restoration and protection activities should be targeted. Develop additional indicators and communication products that evaluate the status of watershed conditions.
- Determine appropriate ways to use monitoring data collected for the state integrated assessments to supplement the nontidal network data in order to identify geographic areas to target for reduction of nutrients, sediment, and contaminants.
- Work with CBP partners to improve the quality and spatial resolution of information on the time history of land use, land-use practices (including implementation of BMPs), application rates of fertilizers and manure, point source loading, atmospheric deposition, and other causative factors within the watershed. ***Without improved spatially specific time series data on these causative factors, the water quality data***

products will have very limited utility for determing the effectiveness of management actions.

Document Water-Quality Change

The STAC review identified the need for improved information on the changes in nutrient and sediment concentrations and loads over time in order to make informed management decisions (STAC 2009a). The CBP NTN was developed to provide consistent information on changes over time for nutrients and sediment loads and concentrations. Review of the state of information in 2004 revealed that many state and locally funded water quality monitoring programs could not be used for documenting water quality change over time. Although these water quality databases are a source of some of the most consistent, extensive, long-term datasets available in the Bay watershed, different water quality collection techniques and lack of associated flow measurements make this data incompatible with the NTN for documenting change over time (CBPO 2004). In order to compute loads and determine flow-adjusted trends in nutrients and sediment it is essential that monitoring sites be located at gaging stations and that sampling occurs during all flow regimes (including targeted storm sampling). Flow-adjusted trends are the best known analysis to determine the impacts of management actions on water quality. Therefore, the CBP NTN is the most appropriate available dataset to document water-quality change over time across the entire watershed. The recommended activities for further analysis of this data include:

- Analyze nutrient and sediment loading trends at newer NT network sites. The following issues require further evaluation:
    - How do we describe the spatial variability of concentrations and loads for sites with only 5 years of data? How do we describe the uncertainty of these estimates?
    - How do we evaluate trends in these shorter records and assure ourselves that the identified trends are not merely the product of normal hydrologic variations, but actually represent underlying changes in watershed processes?
    - Improve techniques for data analysis that might identify the importance of different sources and trends in the different sources (specifically point sources, non-point source stormflow sources, or ground water). This can be accomplished by analysis of baseflow vs. storm flow.
    - Conduct basinwide analysis of source changes and concentration changes using techniques such as a time-variant SPARROW to determine if changes in sources are a viable explanation for changes in water quality observed throughout the watershed.
- Determine what kinds of ongoing communication products can be developed for sites with long records (e.g. more than 20 years). Products should be considered that include time histories of average concentrations and loads as well as products that remove the effect of year-to-year flow variations, in order to consider long-term progress towards water quality goals.
- Determine appropriate ways to use existing state, local, and river basin commission ambient monitoring data collected at sites without stream flow data and targeted storm sampling to document change over time (referred to as "ambient data"). To do this, a review of methods of data analysis that are appropriate to the level of knowledge we have about the streamflows is needed. An important question is how

to effectively use data where the flows are relatively poorly known, and then evaluate if this is better than not using the data at all.

- Seasonal-Kendall trends (calculated using ambient data) at ungaged sites provide a valuable supplement to flow-adjusted trends in the NT network.
- For selected communication products, the Seasonal-Kendall trend results on the raw concentration data may add useful information.

Explain Water-Quality Change

The STAC review identified the number one priority in the watershed monitoring and assessment program is to explain water quality change over time (2009a). This information is essential in order to assess the effectiveness of management actions. Understanding effectiveness in the watershed will, in turn, support linking such improvements with measures in the tidal tributaries (tidal fresh regions) of the Chesapeake Bay. Currently, the quality and spatial resolution of information on the history of land use, land-use practices (including implementation of BMPs), application rates of fertilizers and manure, point source loading, atmospheric deposition, and other causative factors within the watershed is lacking. ***Without improved spatially specific time series data on these causative factors, the water quality data products will have very limited utility for determing the effectiveness of management actions.***

The following information has been idenfied as lacking and essential to explain water-quality change:

- changes in nutrients applied to the landscape
- changes in atmospheric loadings
- changes in ground-water flow and quality as it affects surface water
- changes in land use and in land use practices including implementation of specific BMPs.
- changes in point source loadings from POTWs, industrial sources, and animal feeding operations
- implementation of management actions including changes in treatment systems, implementation of agricultural and urban BMPs on the landscape or along stream corridors – note that this information doesn't have to give precise locations of these practices, but simply needs to be able to be aggregated to the scale of the monitored watersheds.

Recent efforts to better quantify the factors affecting water-quality change revealed the CBP office does not have adequate data sets to characterize changes in sources over time or implementation of management actions. Therefore, effort and resources need to be increased to improve these data to better explain water-quality change. The MRAT team has concluded that the implementation data available at this time is insufficient for the evaluation of the effect of management actions. Data-management efforts may be focused on those watersheds with active monitoring programs to support evaluation of management actions. An effort is needed to: 1) assemble and document historical information on land use, point sources, population, and agricultural activity, 2) Create a sustainable process for tracking watershed information in the future, and 3) make this information available to support assessment, research, and modeling efforts.

Several promising techniques have been demonstrated (Hirsch, oral pres. 2009) that describe changes in nutrient and sediment concentration over time in relation to different source sectors—such as point sources and agricultural runoff. We recommend that these approaches be used in conjunction with improved implementation databases to selectively describe the effects of management actions in the watershed.

Utilize small watershed studies to assess effects of management actions

The STAC review identified the need to both understand the effectivness management actions and to understand the condition and trends of water quality at different spatial scales and in different landuses (STAC 2009a). Small watershed studies provide the best opportunities to assess the effectiveness of management actions and understand the multiple factors affecting water-quality change. These smaller systems usually have less varied pollution sources than larger systems so that pollution sources and the subsequent management actions to mitigate the pollution can be tracked can be identified. Information on the effectiveness of management actions is best obtained in these smaller watersheds where the management actions cover a significant part of the entire watershed so that the cumulative effect of the multiple management actions will be measurable in the water quality response. Previous studies show that there must be a large expected reduction in nutrient loading in a watershed to have a measureable response in water quality (McCoy et al. 1999).

It is recommended that the CBP NTN should locate a sentinel long-term nontidal network site in selected small watershed study areas in order to provide a long-term monitoring and assessment commitment to the watershed study. It is recommended to target 2-3 small watersheds study areas where there is an increase in management activity and implement a "nested" water quality monitoring approach. Watersheds would be chosen using the criteria developed by STAC. Study areas identified in the STAC workshop for increased implementation funding should be considered high on the candidate list. (STAC 2009b).

Existing Small Watershed Studies in the Chesapeake Bay watershed

There are over 60 studies within the watershed where small watersheds are being monitored and assessed. Appendix A, tables 1A and 2A detail small watershed studies being conducted throughout agricultural and urban landuses in the Chesapeake Bay Watershed (MRAT 2009 Partnership Team, in progress). The studies vary in the parameters sampled, frequency of sampling, sampling design, and quality assurance levels. The utility of this data to document and explain water quality change and the quality of the data should be evaluated. Also, the outcomes of many of these studies have not been synthesized and documented in a way that allows for future research to learn from the cumulative results of these previous studies. It is recommended that a "lessons learned" analysis be conducted on small watershed projects throughout the watershed in order to produce documentation of what water monitoring and implementation does and does not work in different landscapes throughout the watershed.

In many of the watersheds listed in Appendix A, tables A1 and A2, the level of implementation of management actions might be too small to see measureable responses in water quality, thus not making them ideal for a study that evaluates the effectiveness of management actions. In the spring of 2009, the Chesapeake Bay Program's Scientific and Technical Advisory held a workshop series that developed recommendations for monitoring small watersheds. During the workshop several watersheds were identified that will receive significant amounts of funding from the Farm Bill to increase implementation in agricultural watersheds (STAC 2009b in progress). These watersheds were on a list of priority agricultural watersheds determined through an extensive prioritization process by the National Resources Conservation Service and other state and federal partners (Figure 4). The watersheds that have been tentatively identified during the STAC workshop as highest priority for increased implementation funding included the Nanticoke River (Maryland), the Conewago Creek (Pennsylvania) and Smith Creek (Virginia, Shenandoah Valley). It is expected that other watersheds will be added to this list; these watersheds show promise as areas where partnering opportunities could be the greatest because implementation rates and local commitment will likely be high.

STAC identified the following criteria for selecting small watersheds to evaluate the effects of management actions:

- high levels of nutrients and sediments yields from the watersheds (i.e. potential for drastic reduction in pollution)
- existing water quality impairments
- a predominate landuse is present, allowing for evaluation of isolated management actions
- potential for high levels of management practice implementation
- high surface to groundwater delivery (decrease effects of lag times on water quality response)
- pre-existing or historical water monitoring programs
- large amount of local interest and engagement in improving watershed health
- partnership with those planning and carrying out these management actions is possible

Small watershed study designs

The goals of the STAC workshops were to: 1) determine guidelines for monitoring in small agricultural watersheds and 2) target small watersheds for increased implementation as a coordinated effort to evaluate the effectiveness of conservation activities (STAC 2009b in progress). The 2008 Farm Bill included a Chesapeake Bay Watershed Initiative which provides an additional $188 million into the Chesapeake Bay Watershed over the next four years; additional funding will increase the amount of implementation of conservation projects such as the targeted state agricultural cost share funds and new/continuing agricultural grant programs. Although the STAC workshops were focused on agricultural watersheds, the basic recommendations can be used as guidelines for small watershed monitoring in other types of landscape types.

The outcomes from the STAC workshop included criteria for targeting watersheds for increased implementation, developing monitoring designs for small watersheds, and identifying information needs about the watershed to perform a management actions effectiveness assessment. ***In order to evaluate the effectiveness of management actions, STAC participants identified the following spatial and temporally-specific information as critical: changes in land activities, management actions, and water quality.*** Additional information is needed on watershed characteristics that affect "response time" in small watersheds such as ground-water residence times and sediment storage and release from flood plains and reservoirs.

STAC recommends the following for watersheds characteristics and information requirements in order to evaluate the effectiveness of management actions. STAC participants developed the following guidelines to link water quality response to management actions (STAC 2009b in progress):

- Watersheds should be small (suggested 10-100 km^2)
- Conservation implementation must be high enough to expect to see a response in the water. It is unlikely that monitoring the effectiveness of an individual conservation practice can yield a detectable nutrient or sediment change. Calculation of expected nutrient or sediment reduction should be done prior to monitoring.
- Temporally and spatially-explicit crop cover and production data provided at field level scales (agricultural sub-watersheds).
- Information on pollution source, location, quantity and timing must be available (i.e. fertilizer and manure application rates). These data need to be given at spatial scales finer than the county level; information is not currently available at field level.
- Tracking of and access to conservation practice information in time and at the field level (or scales finer than county). This includes existing and projected practices. Data disclosure should be resolved prior to any monitoring.
    - Implementation rates for larger units (e.g., HUC 12 watersheds or counties) would not provide enough resolution to select watersheds or interpret monitoring data from small watersheds.
- Information on watershed characteristics such as groundwater vs. surface flow contribution, nutrient mass balance, P soil saturation, etc.
- Monitors use recommendations outlined in the STAC report on monitoring designs and sampling parameters at appropriate spatial and temporal scales. The monitoring commitment should be long-term given the presence of lag-times.
- Historical data on water quality and landuse available.
- Historical or on-going environmental monitoring data should be identified; identify monitoring partners.

Potential Activities to utilize small watershed studies

The types of watershed studies that evaluate the effects of management actions are costly and information intensive. For example, the state of Maryland expends about $750,000 per year on monitoring in the Corsica small watershed study. Therefore, it is not the intent for the Chesapeake Bay's watershed monitoring and assessment program to coordinate an intensive watershed study such as this, only to partner with watershed groups, non-governmental organizations, river basin commissions, and others who are involved in these studies and provide monitoring and assessment support. Potential partners include Natural Resources Conservation Service, National Fish and Wildlife Federation, USGS (Fairfax Co. and Clarksville projects), MD 2010 Trust Fund, Baltimore Ecosystem study, and others who are doing intensive watershed studies. Recommended activities to utilize small watershed studies include:

- Synthesize lessons learned in past and on-going small watershed studies and ground-water quality studies and integrate these results into communication products to support watershed assessments and management decisions. The report needs to explain how natural variability (wet year-dry year) and time lags due to ground water flow paths (for nitrate) or deposition and resuspension (for sediment and phosphorus) will make it difficult to see a water quality response to management actions in a 2-3 year time frame. It is also essential to integrate modeling activities in these reviews of management effectiveness.
- The CBP NTN should locate a sentinel long-term nontidal network site in selected small watershed study areas in order to provide a long-term monitoring and assessment commitment to the watershed study. We recommend target 2-3 small watersheds study areas where there is an increase in management activity and implement a "nested" water quality monitoring approach. Watersheds would be chosen using the criteria developed by STAC. Study areas identified in the STAC workshop for increased implementation funding should be considered high on the candidate list (STAC 2009b).
- Partner with small watershed study researchers and provide synoptic surveys and other monitoring support to small watershed studies to support evaluation of management actions.
- Work with partners to encourage an increase in data-management efforts that support the evaluation of management actions. Increased efforts are needed to: 1) assemble and document historical information on land use, point sources, population, and agricultural activity, 2) create a sustainable process for tracking watershed information in the future, and 3) make this information available to support assessment, research, and modeling efforts.

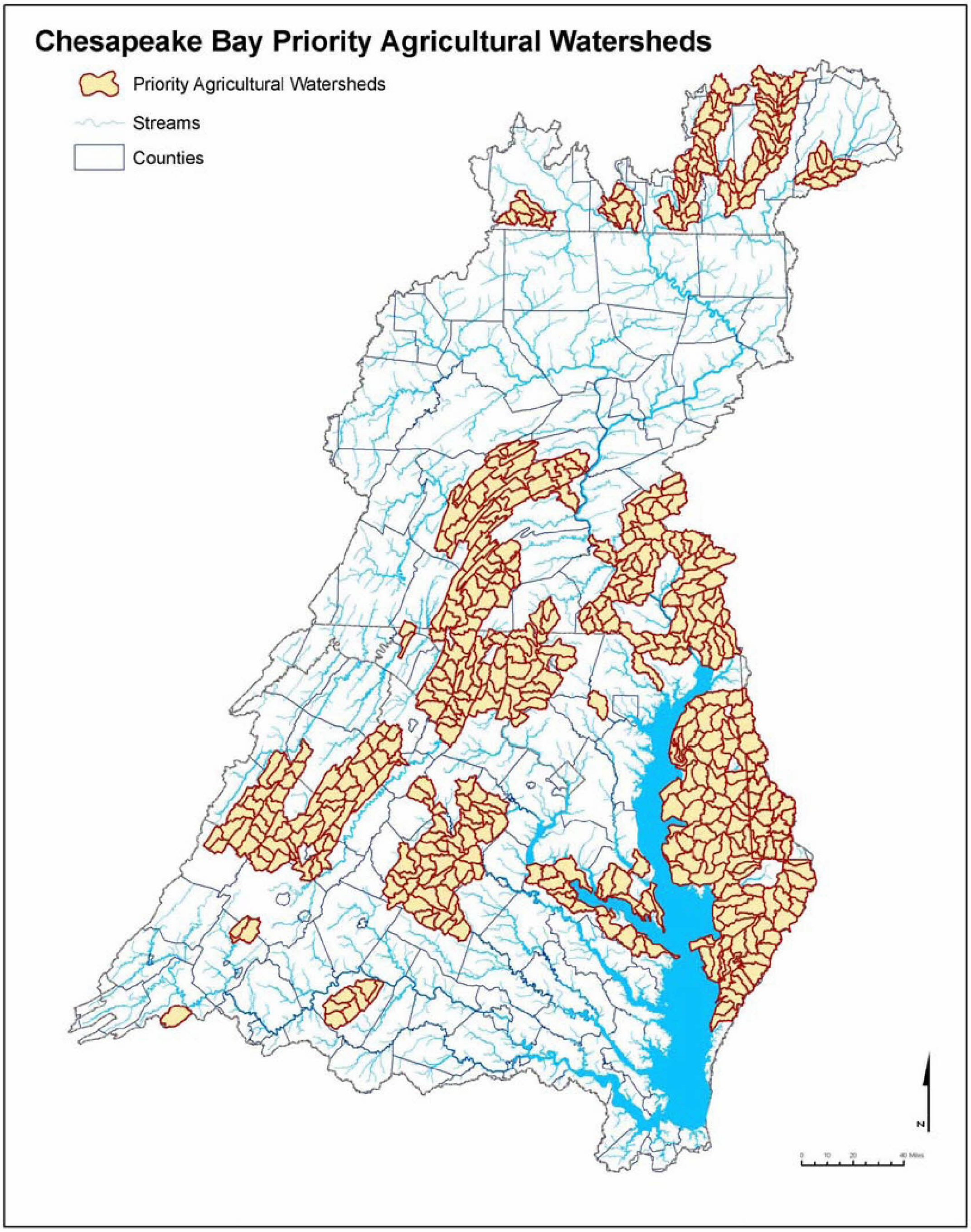

Figure 4. NRCS priority agricultural watersheds in the Chesapeake Bay Watershed

Refine communication products

Prior sections of the report describe recommended improvements to nontidal monitoring and analysis activities; however, the results of these activities must be communicated in a timely and appropriate fashion in order to support effective management and decision making. Communication products must be tailored to meet the differing needs of resource managers and the broader public audience.

The STAC review identified the need to provide sound communication information about water quality relevant to the public and decision makers. There are four areas identified by the MRAT communications team (2009) where improved watershed assessment information is needed:

- Directly linking pollution reductions to management actions
- Identifying water quality success stories and positive water quality trends
- Looking at smaller scale ecosystems
- Highlighting long-term water quality trends, including describing progress that has been made in the past as well as current progress or lack thereof

Addressing each of these topics requires focused topical reporting and the support of detailed technical reports or journal articles. Recommendations for improved communications products for nontidal waters include the development of short summaries of technical articles for widespread communication, improvements to annual indicator presentations in the "Bay Barometer", and improved presentation and access of results for resource managers.

The four recommendations from the MRAT communications team highlights the need to better communicate the effectiveness of management actions as supported through monitoring data. The MRAT optimization and effectiveness team recognizes the need to identify and communicate success stories, however, it also acknowledges the need to present unbiased interpretations based on monitoring data—highlighting improvements as well as lack of improvement as found through comprehensive assessment. This emphasis on assessing management actions will be incorporated with communications products that describe status and trends in water quality condition.

It is essential to determine the priority for developing different kinds of communication products in terms of frequency of reporting, and target audience. An additional consideration is whether these communication products should be developed from NTN sites alone or using supplemental data sources. Consistency in communicating the stories about watershed health trends and conditions should be stressed—particularly when indicators are periodically updated.

Current communication products and gaps

Annual assessments of trends and conditions from the nontidal network monitoring data have traditionally been reported through technical reports and through web sites. A small amount of information has been included in the CBP's primary public communications product, the "Bay Barometer". This report presents environmental health indicators in relation to management goals; the following watershed health indicators have been developed by the nontidal workgroup and are currently included:

- Total nutrient and sediment loads to the Bay (using NTN data and modeled data)
- Stream Health Indicator (Chesapeake Bay Basin-wide Benthic Index of Biotic Integrity)

Neither of these indicators can be related to a management goal at this time and the total of these two products does not provide a comprehensive communication base about the condition and status of water quality in the watershed.

The annual update of trends in the nontidal network provides a comprehensive presentation of status and trends in nutrient and sediment concentrations, loads, and streamflow for 34 long-term monitoring stations. This report, however, does not attempt to describe the link between observed changes and watershed management actions and is intended to provide the support for such analysis. In addition, these data are used along with state ambient monitoring networks for a variety of purposes including the 305b and 303d reports.

Based on a review of current products and historical reports, the following gaps or weaknesses in communication were identified:

- communicating status and trends of nutrient and sediment to a large audience—such as through the Bay Barometer,
- explaining observed water quality change in relation to management actions,
- linking current conditions and long term trends with management goals,
- communicating summary results on management effectiveness for focused studies, and
- incorporating State assessments in Chesapeake Bay communications products.

Proposed communication products

Proposed communication products and indicators for nontidal waters will be used to describe patterns in both space and time throughout the watershed. Spatial patterns will be used to support conditions assessments and targeting of restoration, while temporal patterns will be used to infer effects of management actions.

In the 2007 STAC report "Potential Environmental Indicators for Assessing the Health of the Chesapeake Bay Watershed", STAC made recommendations for possible additional environmental indicators in the Chesapeake Bay Watershed within the following categories: watersheds, water quality, habitat, and living resources (Table 3) (STAC 2007). Inclusion of these additional indicators must be prioritized in relation to the 2009 recommendation to communicate on effectiveness of management actions.

Table 3. Recommendations from STAC workshop on developing environmental health indicators

Watersheds	Stream Corridors	Living Resources
Forest cover acres * Non-tidal wetland acres * Landscape development index Channel ditching/altered connectiveness	<u>a) In-Stream Water Quality</u> N, P, Sed loads (CBP caps) * Selected contaminants (303d) * DO (303d) * pH (303d) * Conductivity Temperature Pathogens (303d) * <u>b) Habitats</u> Physical/hydrologic conditions - in streams - in riparian zones - in floodplains Connectiveness of riparian buffers Stream hydrologic stability	<u>a) In-Stream</u> Benthic IBI Basin-wide Fish IBI Periphyton indicator <u>b) In Watershed</u> Bird popn condition Amphibian popn condition Mammal popn condition

* goal or criterion is currently available

Note that the data supporting these indicators is updated on a wide range of time scales—from annual to decadal. For example water quality conditions are compiled and assessed on an annual basis, while land cover is updated about every decade through remote image processing. It is important that indicators are chosen that appropriately account for this variation.

The MRAT optimization and effectiveness team suggests that new communications products be developed as part of planned and ongoing analysis activities. A needs analysis should be conducted to prioritize additional communication products for a variety of different water quality and habitat parameters. Indicators to evaluate the effects of management actions throughout the watershed have been identified as a priority by managers. Below are potential activities for improved communication products to support resource managers as they prioritize and evaluate management actions. Potential activities to do do so include:

- Incorporate status and trends indicators based on annual technical reports on the NTN into the CBP “Bay Barometer” to support management and public awareness of watershed conditions and progress.
- Summarize results from enhanced data analysis to communicate understanding of factors affecting change in water quality to a broad audience
- Develop communication products that convey the results of small watershed studies to support watershed assessments and management decisions. Consider “case study” based communication products.
- Consider developing an indicator from NTN and state ambient data for a water quality status indicator.
- Consider developing additional indicators that relay information about the health of watersheds, stream corridors and living resources in the watershed. Consider integrating this information to discuss overall watershed health.

Summary of Recommendations to improve nontidal monitoring, assessment, and communication

The Chesapeake Bay Program's nontidal workgroup and MRAT optimization and effectiveness issue team, consisting of federal, state, river-basin commissions, and academic partners, have identified items needed to address the information needs to "assess the effectiveness of management actions" that were in the Chesapeake Bay's Scientific and Technical Advisory Committee (STAC) review of the Chesapeake Bay monitoring program (STAC 2009a). The workgroup reviewed current programs and activities to identify opportunities to address the information needs and determined where funding is required to support additional activities. Four primary topics have been identified where increased funding or partner efforts are needed 1) improve the Nontidal Water-Quality Monitoring Network, 2) enhance assessment of existing information, 3) utilize small watershed studies to assess effects of management actions, and 4) develop additional communication products.

The nontidal workgroup and MRAT optimization and management team developed cost summaries of the recommended activities in this document that would improve the watershed and assessment program to address the information needs identified in the STAC review (Table 4). The total cost of all suggested activities range from approximately $2 million to $3.7 million per year. These budget estimates are based on the assumption that one NTN monitoring site costs $45,000 per year to operate and one full time employee (FTE) costs $100,000 per year, although actual per-site costs may vary. The workgroup has prioritized these activities ranking them as high, medium, and low. It was consensus of the group that to meet new management objectives the cost of the highest priority activities range from $645,000 to $720,000 per year. An evaluation of these costs incorporating the implications of partnering opportunities should be further investigated.

Recommended high priority activities

1. Maintain the continuity and increase stewardship of the current CB nontidal water-quality network (NTN) and its data -- *the historical investment is substantial and is crucial to maintain. We must improve management of the data and make it more accessible to the science and management communities.*

2. Enhance data analysis of the NTN data and selected supplemental networks to document and communicate the status of trends in water quality and explain changes in water-quality condition—*1) Utilize long-term data sets to communicate patterns of change over time and explain effects of changes in the watershed. 2) Utilize sites with the shorter period of record to describe the status of concentrations and loads across the watershed to support targeting of restoration efforts. 3) Refine methods to use additional partner monitoring to improve spatial resolution of current assessments. 4) Use available data to evaluate and improve watershed models.*

3. Increase stewardship and improve the information of important watershed activities including tracking management actions.—*The MRAT team has concluded that the implementation data available at this time is insufficient for the evaluation of the effects of management actions. Data-management efforts may be focused on those watersheds with active monitoring programs to support evaluation of management actions. An effort is needed to: 1) assemble and document historical information on land use, point sources, population, and agricultural activity, 2) create a sustainable process for tracking watershed information in the future, and 3) make this information available to support assessment, research, and modeling efforts.*

4. Make strategic improvements to the NTN to support assessment the effects of management actions in a more quantitative fashion in the future — *additional sites in:*

  a. watersheds with predominantly urban land use,

  b. watersheds with predominantly agricultural land use,

  c. small basins where substantial BMP investments are planned, and other watersheds that can be used for baseline conditions.

5. Utilize information from small watershed studies to better assess the effectiveness of management actions.—*Synthesize lessons learned in past and on-going small watershed studies and ground-water quality studies and integrate these results into communication products to support watershed assessments and management decisions.*

Additional recommended activities

It is suggested that the highest priority items be addressed first with any additional funding to the nontidal water quality monitoring program. In the current economic climate, where funds for monitoring might be reduced at the state level, it is essential to continue to maintain current monitoring and analysis wherever possible and incorporate the above higher priority activities when able. It should be noted that there are partnership opportunities that could decrease the total cost of these activities, however, in light of the unstable economic climate, such partnership opportunities should be thoroughly evaluated for longevity of funding. The highest priority activities represent about 20-30% of the budget of the total recommended activities to improve watershed monitoring and assessment. The remaining activities identified by the nontidal workgroup in table 4 should also be considered as funding becomes available.

Table 4. Rough estimated costs for improved watershed monitoring and assessment

Activity	Existing activities: currently coordinated by CBP, (#FTE)	Existing activities: currently coordinated by partners, (#FTE)	Additional support needed (#FTE)	Partnering opportunity	Does the effort vary by stage of activity?	Priority level	Total estimated additional cost ($)	Total estimated cost ($) of highest priority activities
Topic 1: Enhancing the assessment of existing information								
Status: Stewardship of data from maturing NTN sites	0.5	USGS, 0.25	0.5-1	USGS/States	Yes	High	50,000-100,000	50,000-100,000
Status: Continue to use and improve CBP modeling tools for targeting	2	USGS, 0.5	0.25-0.5	USGS/CBP-modelers	Yes	Low	25,000-50,000	
Status: Improve and update stream health indicator	0.5	ICPRB and States,1	1	ICPRB/UMCES	Yes	Medium	100,000	
Status: Determine how data from state integrated assessments can be used to target - Database management	0	States, 0.25	0.25-0.5	States/ICPRB/CBP	No	Low	25,000-50,000	
Status: Determine how data from state integrated assessment can be used to target - Synthesize	0	States, 0.25	0.25-0.5	States/ICPRB/CBP	Yes	Low	25,000-50,000	
Documenting WQ change: Yearly updates of nontidal trends	0.2	USGS and States, 1	0.25-0.5	USGS/States	No	High	25,000-50,000	25,000-50,000
Documenting WQ change: Develop additional trend analysis techniques for shorter time periods	0	USGS, 1	1	USGS/Academics	No	Medium	100,000	

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Table 4 (Con't)

Activity	Existing activities: currently coordinated by CBP, (#FTE)	Existing activities: currently coordinated by partners, (#FTE)	Additional support needed (#FTE)	Partnering opportunity	Does the effort vary by stage of activity?	Priority level	Total estimated additional cost ($)	Total estimated cost ($) of highest priority activities
Documenting WQ change: Develop analytical techniques that use ambient state data for load and trend analysis	0	States and Academics, 4 FTE	1-3	USGS/States/Academics	Yes	Low	100,000-300,000	
Explain WQ change: Stewardship of watershed variables (landuse change, BMP information, etc.); data assimilation and quality assurance	1	States, Academics and Watershed groups, 5 FTE	4	CBP Science Team/States/ Watershed groups/Counties/NRCS/USDA/ NFWF/Academics	No	High	400,000	100,000
Explain water-quality change and assess the effectiveness of management actions: regional NTN sites, emphasis on long-term sites (≥10 years)	0	USGS and States, 1.25	1-2	USGS, Academics (SERC, VA-tech, etc.), States, Mid Atlantic WQ Network	No	High	100,000-200,000	100,000

Table 4 (Con't)

Activity	Existing activities: currently coordinated by CBP, (#FTE)	Existing activities: currently coordinated by partners, (#FTE)	Additional support needed (#FTE)	Partnering opportunity	Does the effort vary by stage of activity?	Priority level	Total estimated additional cost ($)	Total estimated cost ($) of highest priority activities
Topic 2: Enhancing the nontidal water quality network								
Address source sectors in regional network - at a variety of scales (add 6-12 sites)	0	0	NA	NTWG members	No	Low	270,000-540,000	
Implement sites in targeted small watersheds with enhanced implementation -ag and urban landuse (add 6-18 sites)* Assumes large amount of monitoring already being done by partners in each small watershed	0	0	NA	NTWG members	No	High	270,000-810,000	270,000
Add sites in coastal plain to improve load estimates and integrate with tidal monitoring (add 6-12 sites)	0	0	NA	NTWG members	No	Low	270,000-540,000	

Table 4 (Con't)

Activity	Existing activities: currently coordinated by CBP, (#FTE)	Existing activities: currently coordinated by partners, (#FTE)	Additional support needed (#FTE)	Partnering opportunity	Does the effort vary by stage of activity?	Priority level	Total estimated additional cost ($)	Total estimated cost ($) of highest priority activities
Topic 3: Utilizing small watershed studies								
Utilizing small watershed studies: Synthesis of lessons learned, data analysis and assessment in new watersheds	0	States, Watershed groups, Academics, 5 FTE	1 FTE	States/ Watershed groups/Counties/NRCS/USDA/ NFWF/Academics	No	High	100,000	100,000
Small watershed studies: Synoptic surveys and other monitoring support. *Assumes large amount of monitoring already being done by partners in each small watershed	0	0	varies	USGS/States/Academics	No	Medium	100,000-200,000	
Topic 4: Producing additional communication products								
Producing additional communication products: Science communicator: Status and trends indicator, other communication products	0.25	States and Ecocheck, 1 FTE	1	Ecocheck/ UMCES/USGS/Academics	No	Low	100,000	
Total Cost							2,060,000-3,690,000	645,000-720,000

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STAC 2009b. Small Watershed Monitoring Designs. Outcomes from the STAC workshops on small watershed monitoring. April and May 2009. In progress.

Appendix A – A Review of BMP Studies in CBP Small Watersheds

Table A1. Agricultural BMP Studies in CBP Small Watersheds

Monitoring Program	BMP Effectiveness Data			N, P & Sediment Loads	Biota	References
	Type & Location	Land Use, Land Cover Soils, etc.	WQ Data			
STATE /EPA §319(h) TMDL MONITORING						
PDEP/ SRBC – Conestoga R. incl. Muddy, Cocalico, Mill, Little Conestoga and Lititz Creeks		X	X	X	X	*http://www.srbc.net/pubinfo/techdocs/publication_257/techreport257.pdf*
PDEP/USGS – Pequea-Mill Cr. NMP, (1993-01) Stream Fencing, Big Spring Run	X	X	X	X	X	*http://www.depweb.state.pa.us/watershedmgmt/lib/watershedmgmt/nonpoint_source/monitoring/pequeamillcreekmonitor.pdf* *http://pa.water.usgs.gov/reports/wrir_00-4205.pdf* *http://pubs.usgs.gov/fs/2006/3112*
PDEP– Stroud Preserve NMP Rip. Forest Buffers (1993-2002)	X	X	X	X		*http://www.depweb.state.pa.us/watershedmgmt/lib/watershedmgmt/nonpoint_source/monitoring/stroudmonitor.pdf*
MDE Corsica R. (cover crops, manure removal)	X	X	X	X		*http://www.dnr.state.md.us/watersheds/surf/proj/wras.html*
VDEQ Smith Creek TMDL	X	X			X	*http://www.deq.virginia.gov/export/sites/default/tmdl/implans/smithip.pdf*
VDEQ Cooks Creek (bacteria TMDL)		X	X		X	*http://www.deq.virginia.gov/export/sites/default/tmdl/apptmdls/shenrvr/cooksfd1.pdf*
VDEQ Muddy Creek TMDL Rockingham Co. (Livestock Fencing)	X	X	X			*http://www.deq.virginia.gov/export/sites/default/tmdl/implans/nriverip.pdf*
VPI Stony, Mill Creeks & N. Fork Shenandoah (bacteria TMDL)		X				*http://www.deq.virginia.gov/tmdl/apptmdls/shenrvr/nfshen.pdf*
OTHER COUNTY, STATE & FEDERAL BMP ASSESSMENTS						
Lancaster Co. Cons. District – Mill Cr. Watershed Implement-ation Plan (Conestoga R.)	X	X	X		X	*http://www.eli.org/pdf/MillCreekPA_2006.pdf*
USDA/PDEP/USGS - Conestoga Headwaters Rural Clean Water		X	X			*http://www.water.ncsu.edu/watershedss/info/rcwp/paprof.html*
USDA– Tuckahoe R. (Choptank) NFWF (Cover Crops)	X	X	X			*http://www.mda.state.md.us/pdf/tuckahoe_factsheet.pdf*
ARS CEAP – Choptank	X	X	X	X		*ftp://ftp-fc.sc.egov.usda.gov/NHQ/nri/ceap/choptankriverceapfact.pdf*
USDA/MDE Double Pipe Creek Rural Clean Water (1982-1992)	X		X	X		*http://www.water.ncsu.edu/watershedss/info/rcwp/mdprof.html*
MDNR Upper Pokomoke (Manure removal/cover crops)	X	X	X			*http://dnr.maryland.gov/bay/czm/nps/publications/pocomoke_fact_sheet.pdf*
Nomini Creek (1985-1997) Crop lands management (Va.)	X	X	X			*http://water.usgs.gov/wrri/97grants/va97ner3.htm*
Owl Run (1986-1996) Animal waste management (Fauquier Co.)	X	X	X			*http://scholar.lib.vt.edu/theses/available/etd-51198-134142/unrestricted/FINISHED.PDF*
USDA/PDEP/USGS - Conestoga Headwaters Rural Clean Water		X	X			*http://www.water.ncsu.edu/watershedss/info/rcwp/paprof.html*
USDA/ New Castle Co./U. Del. Appoquinimink R. Rural Clean Water Program (1980-1991)	X	X	X	X	X	*http://www.water.ncsu.edu/watershedss/info/rcwp/deprof.html*

Monitoring Program	BMP Effectiveness Data			N, P & Sediment Loads	Biota	References
	Type & Location	Land Use, Land Cover Soils, etc.	WQ Data			
ACADEMIC & RESEARCH INSTITUTION STUDIES						
UM St Mary's College – St. Mary's River Watershed		X	X	X	X	*http://www.stmarysriver.org/pdfdocs/report_p* and *http://www.stmarysriver.org/pdfdocs/report_phase1_SS.pdf hase1_WC.pdf*
SERC – Rhode R. Watershed		X	X			*http://www.serc.si.edu/labs/ecological_modeling/landuse_trends.aspx*
W.Va. DEP/ CVI - Mill Creek (Opequon) Fencing, Riparian Buffer, Bank Stabilization	X	X	X		X	*http://www.opequoncreek.org/WatershedBasedPlan.html*
NFWF/VPI – Stream Fencing in Shenandoah R. basin						*http://www.nfwf.org/AM/Template.cfm?Section=Live_Stock_Exclusion*
NFWF/ VPI – Innovative Cropping in Shenandoah R. Basin		X				*http://www.nfwf.org/Content/NavigationMenu/ChesapeakeBayStewardshipFund/ConservationResults/AgriculturalConservation/CroplandConservation/default.htm*
NFWF/VPI - Stream fencing in Rockingham & Augusta Co. (Va.)		X				Mossy, Naked & Long TMDL: *http://www.deq.virginia.gov/export/sites/default/tmdl/implans/drafts/mossyip.pdf*
Tri-County Conewago Creek Association (Pa.)		X			X	*http://www.depweb.state.pa.us/watershedmgmt/lib/watershedmgmt/nonpoint_source/implementation/conewago_creek.pdf*
CITIZEN MONITORING IN RURAL AREAS						
Smith Creek Va. - Friends of the N. Fork Shenandoah R.			X		X	*http://www.fnfsr.org/whatwedo/monitoring.html*
Chester River Keeper						
Sassafras River Keeper						
Lancaster Co. Senior Environmental Corps						
Spring Creek Watershed Community			X	X	X	*http://www.clearwaterconservancy.org/CWC%20files/2007_WRMP_Annual_Report_12042008.pdf*; *http://www.springcreekwatershed.org/index.php?option=content&task=view&id=69&Itemid=88*
Patuxent River Keeper						
Nanticoke Watershed Alliance Creekwatchers						*http://www.nanticokeriver.org/Creekwatcher.html*
West and Rhode River Keeper						*http://www.westrhoderiverkeeper.org/reportcard/WR_Report_Card_09.pdf*

Table A2. Urban and Suburban BMP Studies in CBP Small Watersheds

Monitoring Program	BMP Effectiveness Data			N, P & Sediment Loads	Biota	Reference
	Type & Location	Land Use Land Cover Soils, etc.	WQ Data			
URBAN AND SUBURBAN MONITORING						
NSF Baltimore LT Ecosystem Study	X	X	X	X	X	*http://www.iternet.edu/vignettes/bes.html*
Montgomery Co. WQ & Benthic	X	X	X	X	X	*http://www.fosc.org/WaterQuality.htm http://www.anacostia.net/restoration/Reports_and_Data/Action_Agend a.pdf*
DC-DOE WQ & Phytoplankton – Potomac & Anacostia Rivers	X	X	X		X	*http://ddoe.dc.gov/ddoe/frames.asp?doc=/ddoe/lib/ddoe/information2/ water.reg.leg/DC_IR_2008_Revised_9-9-2008.pdf*
MWCOG Anacostia River	X	X	X	X	X	*http://www.anacostia.net/restoration/Reports_and_Data/Action_Agend a.pdf http://www.fosc.org/WaterQuality.htm*
MWCOG Potomac River	X	X	X	X		*http://www.mwcog.org/uploads/committee-documents/bl5fXVpX20080118144813.pdf http://www.owml.vt.edu/projects.htm*
DC DOE - Watts Branch Watershed Restoration Project	X	X	X		X	*http://ddoe.dc.gov/ddoe/frames.asp?doc=/ddoe/lib/ddoe/information2/ water.reg.leg/DC_IR_2008_Revised_9-9-2008.pdf*
MDE 319 – Centerville Stormwater BMPs (Corsica River)	X	X	X	X		*http://www.mde.state.md.us/assets/document/319-2008-Maryland-FINAL-NPS-Annual-Rpt-20090515.pdf*
Villa Nova Urban Storm water Partnership (PA) – LID BMPs	X	X	X			
MDE 319 Frederick Co.- Toms & Bennett Creek Urban Wetlands	X	X	X	X	X	*http://www.mde.state.md.us/assets/document/319-2008-Maryland-FINAL-NPS-Annual-Rpt-20090515.pdf*
Fairfax Co. WQ & Phytoplankton – Gunston Cove			X	X	X	*http://mason.gmu.edu/~rcjones/gc989rep.pdf http://mason.gmu.edu/~rcjones/GC0304Final.pdf*
Occoquan Watershed Monitoring Program, and Chain Bridge	X	X	X	X		*http://www.mwcog.org/uploads/committee-documents/bl5fXVpX20080118144813.pdf http://www.owml.vt.edu/projects.htm*
USGS / Fairfax Co.	X	X	X	X	X	*http://va.water.usgs.gov/projects/ffx_co_monitoring.htm*
City of Portsmith,Va. – Storm Water Monitoring			X			
Chesterfield Co. Va. - Swift Creek Reservoir	X	X	X	X	X	*http://www.chesterfield.gov/content.aspx?id=2854&ekmensel=c580fa7 b_66_118_2854_18 http://www.chesterfield.gov/content2.aspx?id=2852*
Calvert Co. Md. – Mill, St. John's, Back Creeks & Narrows			X			*http://www.gonzo.cbl.umces.edu/PDFs/2007FinalReport07102008.pdf*
NFWF / Opequon Creek						
NFWF / SRBC /PCWEA – Paxton Cr. Storm water Monitoring (Harrisburg)			X	X		
NFWF / CWP – James River Storm water BMPs			X			

Monitoring Program	BMP Effectiveness Data			N, P & Sediment Loads	Biota	Reference
	Type & Location	Land Use Land Cover Soils, etc.	WQ Data			
VDCR Polecat Creek (baseline, pre-development monitoring)			X	X		
VA DEQ Non-Agency/Citizen Monitoring Activities (state-wide and numerous local watershed organizations	X	X	X	X	X	*http://www.deq.virginia.gov/cmonitor/guidance.html* *http://www.deq.virginia.gov/cmonitor/pdf/2008_Summary_of_Non-DEQ_Activity.pdf* *http://www.deq.virginia.gov/waterguidance/pdf/062010.pdf* http://www.deq.state.va.us/cmonitor/pdf/summer07VCWQ_pres7-21-07.pdf
CITIZEN MONITORING						
Alliance for the Chesapeake Bay	X	X	X	X	X	*http://www.acb-online.org/pubs/projects/deliverables-87-3-2004.PDF* *http://www.acb-online.org/monitoring/data/attribute.cfm?type=Water_Quality_Data* *http://www.acb-online.org/pubs.cfm*
South River Fed. & River Keeper Monitoring	X	X	X	X		*http://www.imrivers.com/southriver*
Severn River Keeper monitoring	X	X	X			*http://www.severnriverkeeper.org/monitoring.html* *http://www.severnriverkeeper.org/pdf/SevernReportCard2008.pdf* *http://www.severnriverkeeper.org/restoration.html* *http://www.severnriverkeeper.org/pdf/2006%20Severn%20Riverkeeper%20Monitoring%20Project.pdf*
Magothy R. Volunteer Monitoring	X	X	X			*http://www.magothyriver.org/wp-content/uploads/2007/08/magothy_river_index_08_newsletter_v61.pdf* *http://www.magothyriver.org/our-river/the-magothy-river-index/mri-2006/*
Loudoun Stream Quality Project	X				X	*http://www.loudounwildlife.org/Environmental_Monitoring.htm*
Friends of Powhatan Creek WQ Monitoring Program	X	X	X		X	*http://web.wm.edu/environment/FOPC/FOPC.html* *http://www.jccegov.com/pdf/stormwater/JCC%20Volunteer%20Water%20Quality%20Monitoring%20Program%20web%20powerpoint.pdf*
Reston Association Stream Monitoring	X	X			X	*https://www.reston.org/ParksRecreationEvents/StreamRestoration/MonitoringMaintenance/Default.aspx?qenc=HzT9ACzZbNs%3d&fqenc=gJ0waUvthCNxSiKHN94QoQ%3d%3d* *http://www2.reston.org/parks_rec/Watershed%20Master%20Plan/Exec.%20Summary.pdf*
West and Rhode River keeper	X		X	X	X	*http://www.westrhoderiverkeeper.org/waterquality.php?newyear=2009* *http://www.westrhoderiverkeeper.org/reportcard/WR_Report_Card_09.pdf*
Potomac Conservancy	X	X	X			*http://www.potomac.org/site/wp-content/uploads/pdfs/pc_sonr_web.512kb.pdf*
James River Association	X	X	X	X		*http://www.jamesriverassociation.org/what-we-do/watershed-restoration/*

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